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PRESTO DIGITAL COMPUTER CODE USER'S GUIDE. VOLUME I. SYSTEM OVE--ETC(U)

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PRESTO DIGITAL COMPUTER CODE USER'S GUIDE

Volume I – System Overview

The Boeing Aerospace Company
P.O. Box 3999
Seattle, Washington 98124

30 May 1977

Final Report for Period 17 January 1977–30 May 1977

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

PRESTO, an integrated system of computer codes, has been developed for the PREMPT program to perform EMP response analysis of communications systems.

Volume One of the PRESTO User's Guide presents an overview of the entire PRESTO system and an introduction to the material contained in the other volumes (two through six) of the PRESTO User's Guide series. (cont on p 1)

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SUMMARY

The PRESTO ~~system of computer codes~~ provides engineering users with a tool for expeditiously analyzing electronic systems to determine electromagnetic pulse (EMP) effects. It is expected that ~~the~~ users ~~will~~ have a basic knowledge of digital computer usage, including the FORTRAN language.

FORTRAN. PRESTO consists of three groups of codes: an executive code, application codes, and a modeling library. The executive code provides the interface between the engineering user and the application programs which perform the calculations requested by the user. The modeling library contains subroutines used to model the electromagnetic response of signal cables, power systems, and ground systems.

The PRESTO ~~code~~ interprets the user input, performs the required computation, and generates the output specified by the user.

A modular approach is ~~utilized~~ used in PRESTO to achieve maximum flexibility. The modularity of PRESTO and the independence of the executive control program facilitates the incorporation of additional application codes and modeling libraries applicable to system analyses other than for EMP effects, e.g., radiation effects, structures, flight dynamics, hydraulics, and control systems.

PREFACE

This document presents a System Overview of the PRESTO Digital Computer Code User's Guide. The document is Volume One of the six volumes which make up the guide. Volumes Two through Six have a limited distribution. Readers having an interest in or need for Volumes Two, Three, Five or Six should address a request to:

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1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The PRESTO User's Guide consists of six volumes and is organized as follows:

Volume One	System Overview
Volume Two	Executive Code (ESCORT)
Volume Three	Frequency Domain Analysis Code (TRAFFIC)
Volume Four	*CIRCUS-2
Volume Five	Interface and Display Codes
Volume Six	Modeling Library

This document, Volume One, presents a system overview of the PRESTO integrated system of computer codes. The PRESTO system was developed to provide engineering users with a tool for analyzing electronic systems to determine electromagnetic pulse (EMP) effects. It is expected that the users will have a basic knowledge of digital computer usage, including the FORTRAN computer language.

Section 1.0 of this document provides the purpose and scope, background and the PRESTO system approach to facility response predictions. Section 2.0 provides an overview of the PRESTO code. The numerical accuracy of the code is discussed in Section 3.0, and problem size capability is reviewed in Section 4.0. PRESTO inputs and outputs, both data and control, are discussed in Sections 5.0 and 6.0, respectively; conclusions and recommendations are provided in Sections 7.0 and 8.0, respectively.

* Volume Four was released June 1973 by Harry Diamond Laboratories as Report Number 0062-1.

1.2 BACKGROUND

The development of the EMP analysis codes was initiated under government funding in 1969 by The Boeing Company for use in support of the Minuteman In-Place EMP program. During 1969 through 1973, two numerical analysis codes were developed, i.e., TRAFFIC, for use in analyzing circuits in the frequency domain, and CIRCUS-2, for analyzing circuits in the time domain. Also developed during this period were time-to-frequency domain transforms, frequency-to-time domain transforms, a capability for representing frequency domain equivalent circuits in the time domain, and a library of modeling subroutines.

In 1973 the Defense Nuclear Agency (DNA) funded an effort to integrate the EMP analysis codes into a system of analysis tools the engineer could use with a minimal knowledge of computers or programming. Two criteria were emphasized in the development effort: 1) ease of use by the engineer, and 2) applicability of the codes to a general class of systems analysis problems. As a result of this criteria, much of the work completed on PRESTO since 1973 has been to modify codes developed on the Minuteman program to include more generalized capabilities. Consequently, the PRESTO system has become more user-oriented through development and documentation of a control program, user languages, standard storage and retrieval systems, and a generalized output package.

1.3 APPROACH

PRESTO was developed to perform the computations necessary to predict the functional response of communication facilities subjected to an EMP environment. To accomplish this, PRESTO calculates the EMP coupling to cables and equipment in a facility, compares the calculated induced waveform characteristics with component thresholds, and provides parameters defining the functional response of the facility.

The method of predicting the facility EMP functional response is outlined in Figure 1.3-1 and consists of three elements: 1) electromagnetic analysis, 2) functional analysis, and 3) response analysis. The first element, electromagnetic analysis, results in a definition of the coupling from the EMP environment to the components. As a starting point for the electromagnetic analysis, a facility description is required which defines the collectors of electromagnetic energy, the electromagnetic characteristics of the facility structure, and the electromagnetic coupling paths from the collectors to susceptible components. The electromagnetic response model is a detailed electrical analog of the coupling from the EMP environment to the component terminals.

The second element, functional analysis, culminates in a characterization of the effect of component disruption on facility operation. For this element, a functional description of the facility equipment and equipment interconnection is required. From this description, components critical to the facility operational performance are identified, upset and damage threshold characteristics of the components are determined, and a functional response matrix, which provides a quantitative relationship between the component disruptions and the functional responses within the facility, is developed.

The third element, response analysis, combines the results from the electromagnetic and functional analyses with the EMP environment to predict the facility response. The response analysis is performed with the PRESTO computer code, which calculates the EMP-induced waveforms at components and expected component disruption. The resulting facility functional response caused by the component disruptions can then be determined. The input to PRESTO consists of the electromagnetic response model, the functional response matrix, component thresholds, an EMP environment specification, and analysis controls for sequencing the computations. Once the electromagnetic response model and the functional response matrix are constructed, the versatility of PRESTO allows for assessment of a facility to any EMP scenario by changing the EMP environment specification.

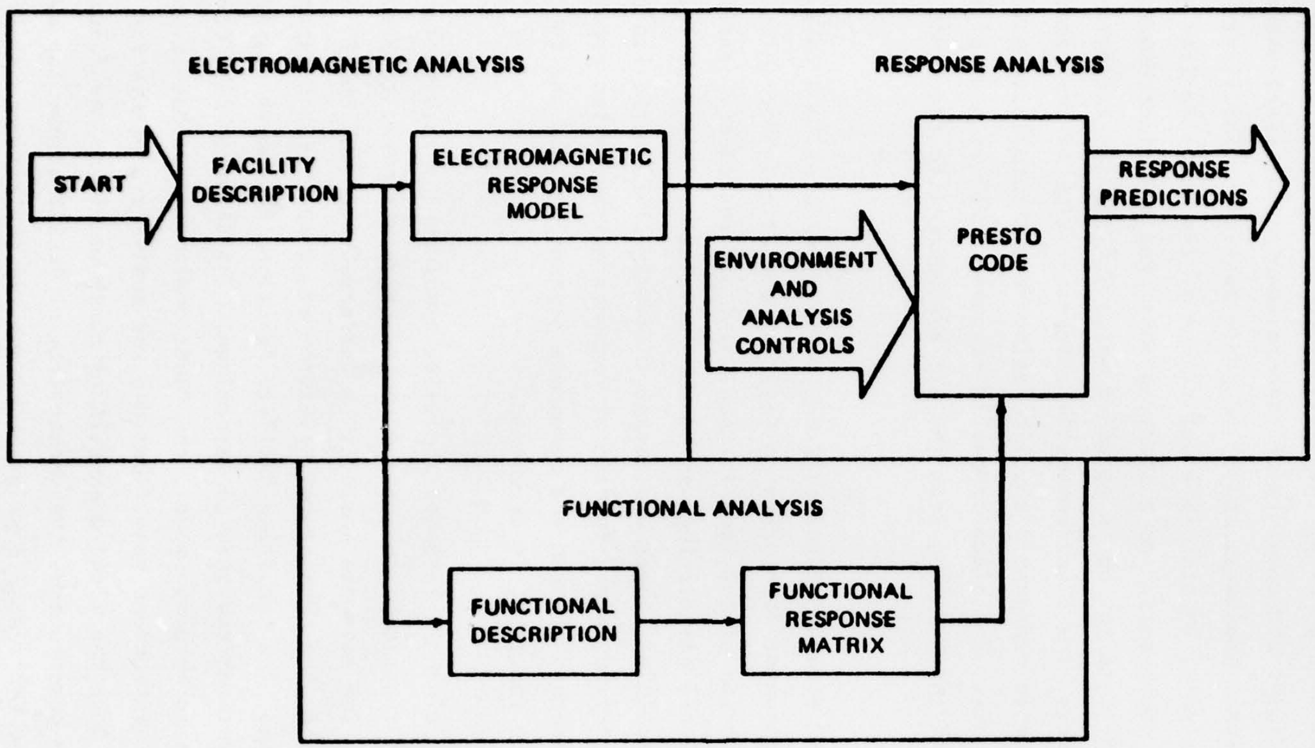


Figure 1.3-1. Facility response prediction methodology.

PRESTO consists of a modeling library for electromagnetic and functional responses, a control program, and codes for analysis and assessment calculations. The output from PRESTO consists of plots of waveforms, spectra, impedances, etc., tabulated listings of models and results, PRESTO reports of component and facility functional response, files, and errors. The flow from input to output is summarized in Figure 1.3-2.

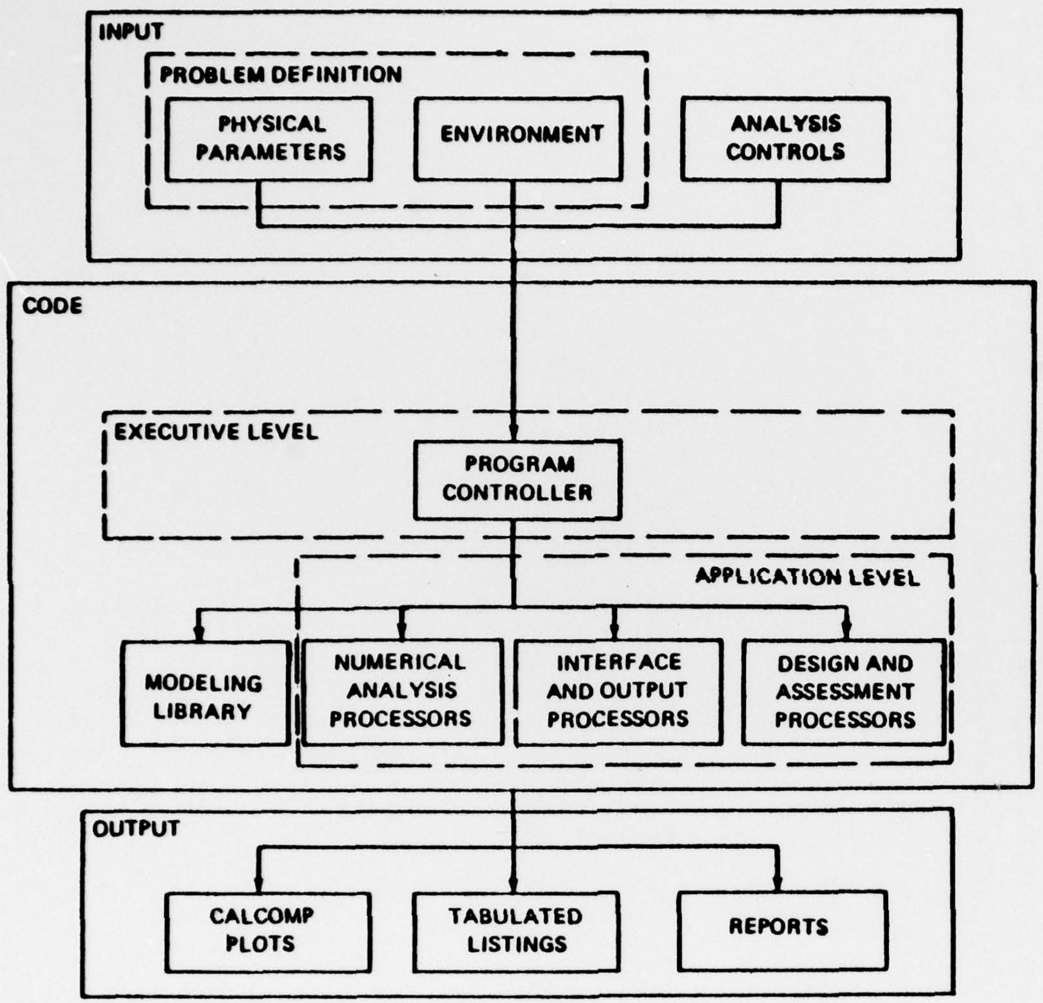


Figure 1.3-2. PRESTO system.

2.0 PRESTO

The PRESTO system of computer codes is a collection of independent application programs and modeling libraries which are linked by an executive control program into an integrated system to solve system analysis problems.

PRESTO consists of three groups of codes: an executive code, application codes, and a modeling library. The executive code provides the interface between the engineering user and the application programs which perform the calculations requested by the user. The modeling library contains subroutines used to model the electromagnetic response of signal cables, power systems, and ground systems.

A modular approach is utilized in PRESTO to achieve maximum flexibility. The modularity of PRESTO and the independence of the executive control program make it a minor task to incorporate additional application codes and modeling libraries to perform system analysis other than for EMP analysis (e.g., radiation effects, structures, flight dynamics, hydraulics, and control systems). This capability to incorporate additional application codes and modeling libraries is discussed in more detail in Volume Two.

The PRESTO code interprets the user input, performs the required computation, and generates the output specified by the user. The PRESTO code processing flow for a typical run is shown in Figure 2.0-1. Section 2.1 presents an overview of the executive code, Section 2.2 presents an overview of the application codes, and Section 2.3 briefly describes the modeling library.

2.1 EXECUTIVE CODE

The PRESTO executive code consists of the control program ESCORT and ESCORT's data base. ESCORT is a general purpose control program designed to aid an engineer in running a set of independent application codes to perform an analysis. ESCORT provides the interface between the engineer and the application codes being used to accomplish a computation task. The user communicates with and directs the processing performed by ESCORT through user supplied inputs written in

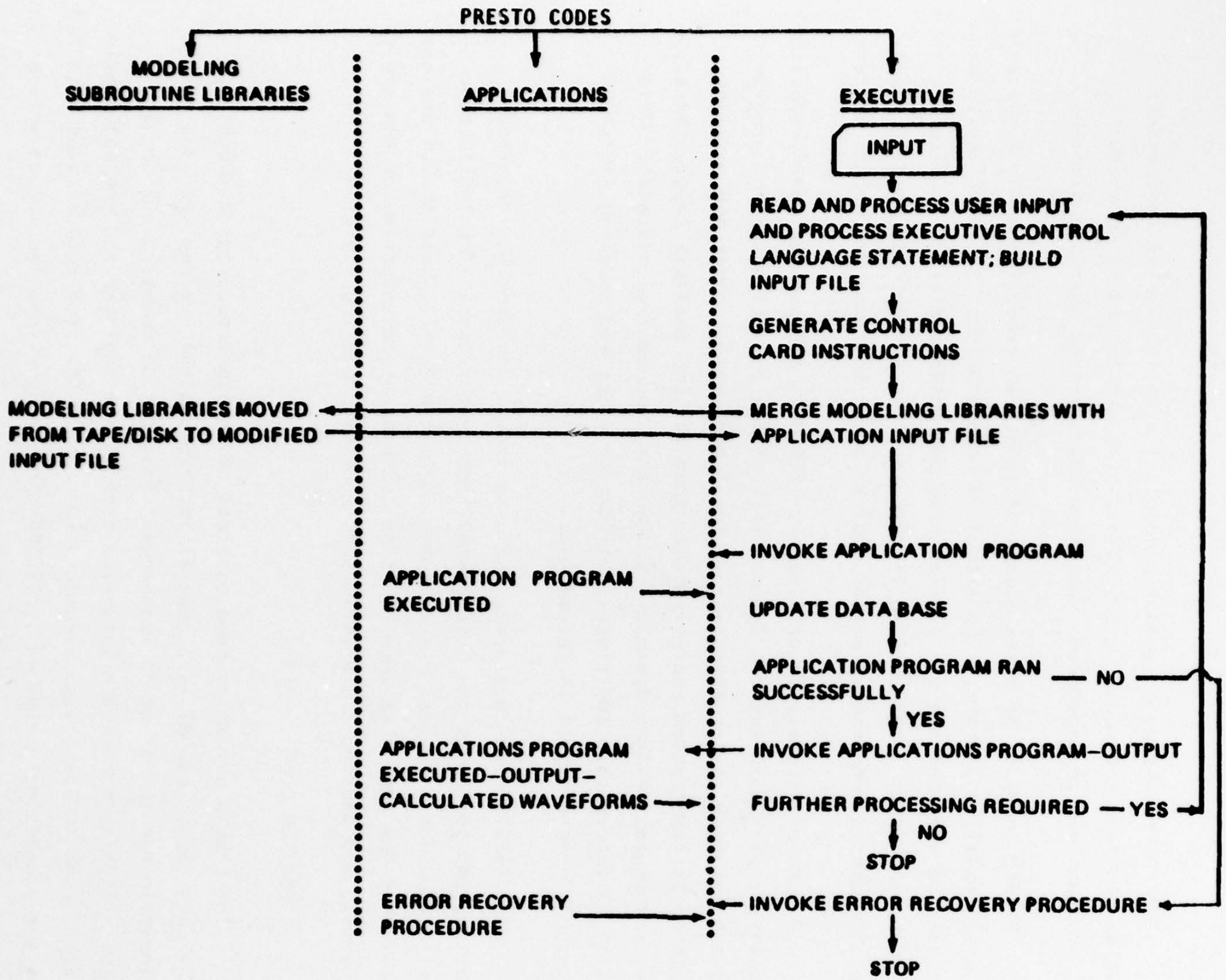


Figure 2.0-1. Example of PRESTO processing flow.

ESCORT Control Language (ECL). ECL aids the user in the generation of data for the application codes, the execution of the application codes on the computer, and the data flow between codes.

ESCORT and each of the application codes operate in the computer as a sequence of unique and independent steps. This permits, without modification, any existing computer code to be used at the appropriate step. The engineer, through the capabilities provided by ESCORT and its data base, is able to integrate the individual application codes into a unified system of codes to accomplish the desired task. ESCORT's data base is a collection of data available to all parts of the PRESTO code. Any part of the PRESTO code may use, modify, or determine a data element value in the data base through the capabilities provided by ESCORT.

The relationship between the user, executive control program, and the individual application codes is shown in Figure 2.1-1. The user prepares the input deck with the appropriate analysis control requirements using ECL. The ECL then provides the interface between the application codes and ESCORT data base. The output is then provided to the user in the desired format, i.e., printer plots and computer reports.

The User's Guide for ESCORT is presented in Volume Two.

2.2 APPLICATION CODES

The PRESTO application codes are invoked by ESCORT to perform the analysis requested by the user. The various application code modules which are included in PRESTO are shown in Figure 2.1-1. The remainder of this section discusses each application code in the PRESTO system.

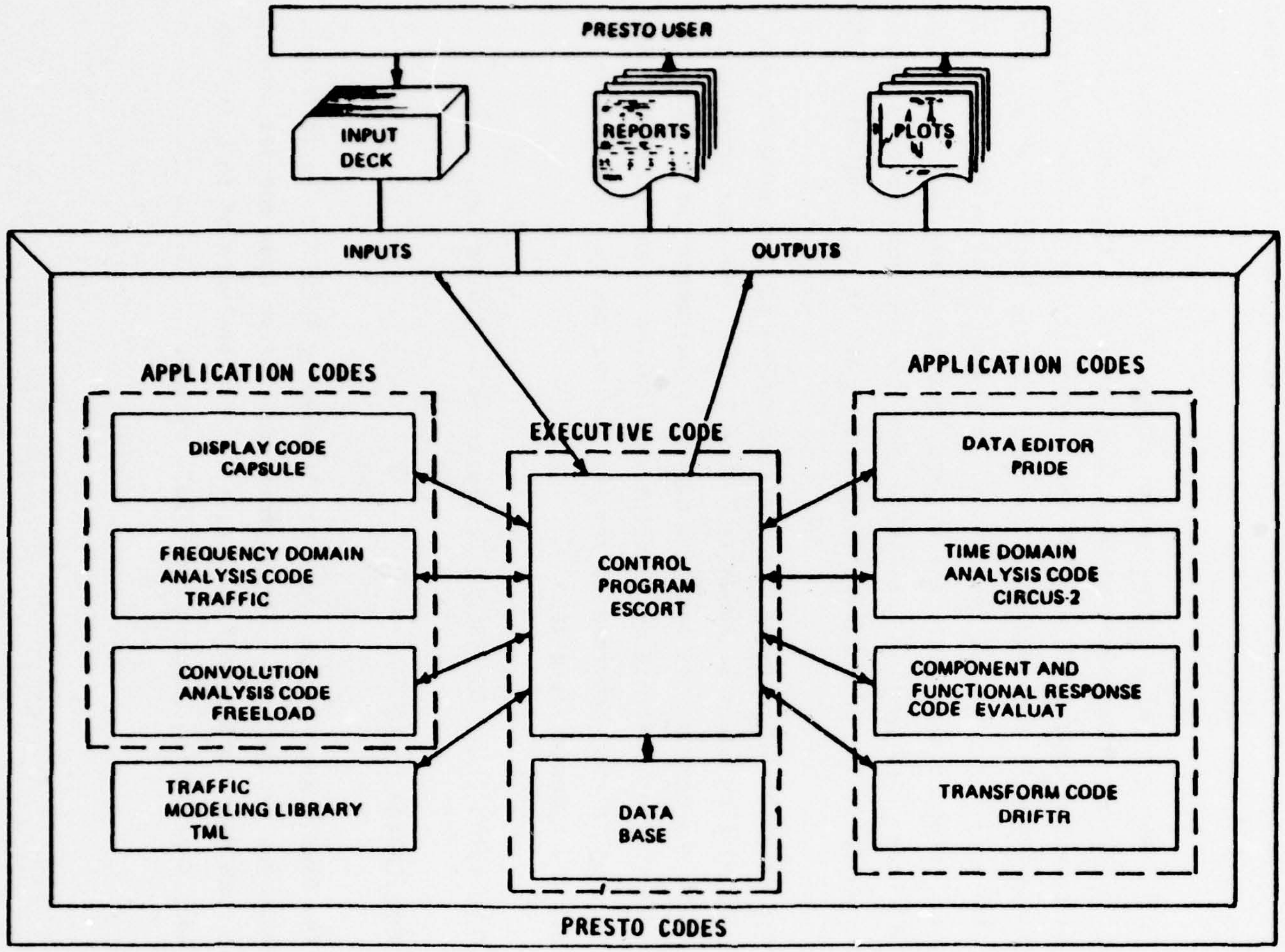


Figure 2.1-1. Interrelation of PRESTO codes.

2.2.1 Frequency Domain Network Analysis Code - TRAFFIC

TRAFFIC provides the capability to perform frequency domain analysis of electrical networks. A major emphasis in TRAFFIC code development has been on efficient simulation of very large electrical networks. Input data include 1) networks of lumped RLCM (resistor, inductor, capacitor, mutual inductor) elements; 2) networks of distributed RLCM elements; 3) numerical admittances with or without associated Norton currents (defined by user written modeling subroutines); and 4) magnetic tape files containing (a) Norton equivalent circuits, and (b) numerical voltages and currents.

The output from TRAFFIC includes 1) magnetic tape files containing Norton equivalent circuit and system function values and 2) printed tabular values and plots of system functions (magnitude and phase) which include node voltages, branch currents, transfer functions, and driving point functions.

TRAFFIC employs state-of-the-art numerical methods including full exploitation of sparse matrix techniques for efficiently solving large network problems. Error monitoring capabilities provide a verification of numerical accuracy, thereby aiding in the validation of results.

The TRAFFIC User's Guide is presented in Volume Three.

2.2.2 Time Domain Network Analysis Program - CIRCUS-2

CIRCUS-2 provides the capability to perform time domain analysis of electrical networks. Input data include values for resistors, capacitors, and inductors, convolution kernels (tabular admittance values versus time), nonlinear elements (i.e., diodes, semiconductor models), voltage sources, and current sources. The input data may be fixed-value or their values may be mathematical functions of the voltages across, and the currents through, circuit elements.

CIRCUS-2 is used to determine circuit upset and damage thresholds in an EMP environment. CIRCUS-2 employs state-of-the-art techniques in numerical integration and sparse matrix methods. The integration method is a numerically stable method currently in use and provides precise error control to assure accurate results. Sparse matrix techniques allow flexibility in modeling and solving large networks.

The User's Guide for CIRCUS-2 is presented in Volume Four.

2.2.3 PRESTO Input/Output Data Editor (PRIDE)

The PRESTO data editor, PRIDE, provides a general data editing capability for data generated by other PRESTO application codes as well as for data obtained from other sources (e.g., test data).

PRIDE is capable of merging data sets, extracting data to make a subset, replacing erroneous data values, interpolating data, and scaling independent and dependent variables. PRIDE also edits names, titles, and miscellaneous data associated with a data set. PRIDE contains an algebraic processing language for adding, subtracting, multiplying and dividing data sets. User supplied subroutines to generate or manipulate data can also be linked with PRIDE.

The User's Guide for PRIDE is presented in Volume Five.

2.2.4 Direct and Inverse Fourier Transform Code (DRIFTR)

The PRESTO Fourier transform code, DRIFTR, provides the capability to perform direct and inverse Fourier transforms using several different techniques, from direct integrating routines to FFT's. DRIFTR will automatically select the optimum technique for performing the desired transform based on the spacing of the input and output waveform data.

The User's Guide for DRIFTR is presented in Volume Five.

2.2.5 Display Code - CAPSULE

The PRESTO display code, CAPSULE, provides a generalized plotting capability. CAPSULE provides numerous routines for obtaining displays of time and frequency domain data in many user-desired formats. These displays are accompanied by labels and explanatory text provided by CAPSULE and/or by user specification.

The User's Guide for CAPSULE is presented in Volume Five.

2.2.6 Component Threshold/Response Comparison - EVALUAT

The EVALUAT code is used to compare the predicted time domain signal induced at a component with a component upset and damage threshold to make statistical probability of failure predictions. The component probabilities of failure and the functional response matrix are used to define probabilities of functional responses for a facility under analysis.

The User's Guide for EVALUAT is presented in Volume Five.

2.2.7 Convolution Analysis Code - FREELOAD

The FREELOAD code provides the capability to convert frequency domain Norton equivalent circuits into a form acceptable for time domain analysis. This capability is provided by the method of characteristics which is similar to the method of convolution integrals. The inputs to FREELOAD are the Norton equivalent circuits; the outputs of FREELOAD are inputs to the CIRCUS code.

2.3 TRAFFIC MODELING LIBRARY (TML)

The TRAFFIC modeling library contains subroutines which can be used to model the electromagnetic environment, penetrations, and electromagnetic coupling paths used by the circuit analysis code TRAFFIC during the calculation of responses of signal cables, power systems, and ground systems.

The Modeling Library User's Guide is presented in Volume Six.

3.0 PRESTO CODE NUMERICAL ACCURACY

There are two primary sources of error in using the PRESTO code to solve mathematical problems. The first is due to an incapability to formulate the problem in terms of mathematical expressions; the second results from the errors associated with approximation of the solution to a mathematical expression using a digital computer code. It is the approximation error that will be discussed in this section. Approximation error occurs when a mathematical problem cannot be solved exactly and a numerical approximation to the solution is used. Quantization error occurs when an analytic function is represented by a set of discrete values. Round-off error occurs because the computer expresses arithmetic operations with limited precision (for PRESTO on the CDC 6600, at least eight significant figures can be expected).

The PRESTO codes that only sort and format data have no numerical errors. ESCORT (executive) and CAPSULE (display) are examples of such codes.

The codes which are subject to one or more of the above numerical errors include TRAFFIC, DRIFTR, EVALUAT, and CIRCUS-2.

The frequency domain analysis program, TRAFFIC, has only quantization and round-off errors. The quantization error is a result of the accuracy with which TRAFFIC reproduces a spectrum of a system function. TRAFFIC will compute the value of the spectrum at intervals of Δf up to a given maximum frequency f_{max}.

If the spectrum changes significantly in a Δf interval or has significant content at frequencies above f_{max}, the TRAFFIC output results will be misleading. The quantization error can be minimized by changing the intervals of Δf and maximum frequency f_{max} and observing when there is no change in the response. On typical problems a 5% error may be expected.

EVALUAT uses one of four transform algorithms that are available. The data being transformed are characteristic functions of known probability density functions, such that Δf and f_{max} can be chosen to produce any desired accuracy. In EVALUAT, Δf and f_{max} are chosen to produce errors of less than 10^{-5} in the computed probabilities.

The primary function of CIRCUS-2 is to solve the ordinary differential equations associated with the circuit being analyzed. The accuracy of the solution method is determined by user input, but it is usually set to a relative error of 0.1%. If the circuit equations are smooth, the computed results will be within 0.1% of the true solution to the equations. For circuits with sharp discontinuities, results will not be this accurate.

A secondary function of CIRCUS-2 is to solve the integral equations associated with FREELOAD (method of characteristics) models. The methods used are not accuracy controlled as in the ordinary differential equations, but they are restricted to a minimum step that is determined by the highest frequency of the data. For this reason, the accuracy of the results of the solutions is determined by the frequency range of the input and is comparable to the accuracy of the Fourier analysis routines.

4.0 PROBLEM SIZE CAPABILITY

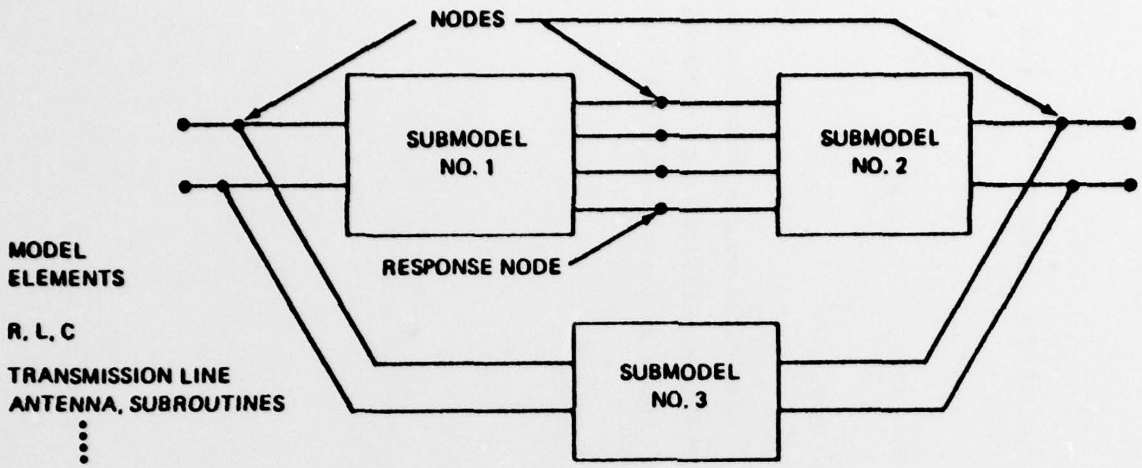
The size of the problem that PRESTO is capable of solving is a function of the type of the analysis to be performed. The following are variables which impact this capability:

1) The number, size, and complexity of the submodels which make up the model,

2) The number of responses desired, and

3) The individual machine limitations.

A single run has routinely handled electrical models described by electromagnetic circuits with thousands of nodes and consisting of hundreds of submodels of racks and cables. Figure 4.0-1 shows an example of electrical model sizes.



FACILITY	SUBMODELS	NODES	OUTPUTS	MACHINE	RUN TIME	CORE
MINUTEMAN WING V/$_{11}$ LF	250	5400	38	CDC 7600	12,000 c.p.u.	170K
MINUTEMAN WING V LCF	600	9400	32	CDC 7600	20,000 c.p.u.	170K
DELTA AECo AUTOVON	270	1850	17	CDC 6600	500 c.p.u.	170K
PICKENS ESS AUTOVON	570	2300	35	CDC 7600	650 c.p.u.	170K

Figure 4.0-1. Examples of electrical model size.

5.0 PRESTO INPUT

PRESTO input consists of 1) analysis controls and 2) a problem definition. Analysis controls involve two types of user instructions; those required by the executive code and those required by the individual application codes. The analysis controls for the executive code provide the user with the capability to dynamically specify the execution sequence of the application codes and to transfer data between application codes. The analysis controls for the individual application codes define the types of analyses the codes must perform, the input data required, the analysis and data processing options, and the desired output data. The problem definition consists of the description of the EMP environment and the physical parameters of the communications facility. The environment description consists of the parameters necessary to define the electromagnetic energy incident on the facility. The physical parameters are a definition of the electrical properties and geometrical configuration of the facility. In particular, the physical parameters describe the predominant electromagnetic coupling paths and critical components within the facility. In addition, the physical parameters include a specification of the particular modeling subroutines to be used. The problem definition becomes the input data for the individual application codes.

The structure of a typical PRESTO deck is shown in Figure 5.0-1. This deck structure could be used to perform a frequency domain analysis of the electromagnetic coupling from an EMP to a facility's critical circuits using TRAFFIC, followed by transformation of the frequency domain results to the time domain using DRIFTR. The deck starts with a control card record. Following the control card record, the PRESTO deck contains alternate blocks of executive code data and application codes (TRAFFIC and DRIFTR) data. The executive code data blocks consist exclusively of analysis controls for the executive code (ESCORT). The application code data blocks consist of both analysis controls and input data. The input data consists of the portion of the problem definition relevant to the particular application code.

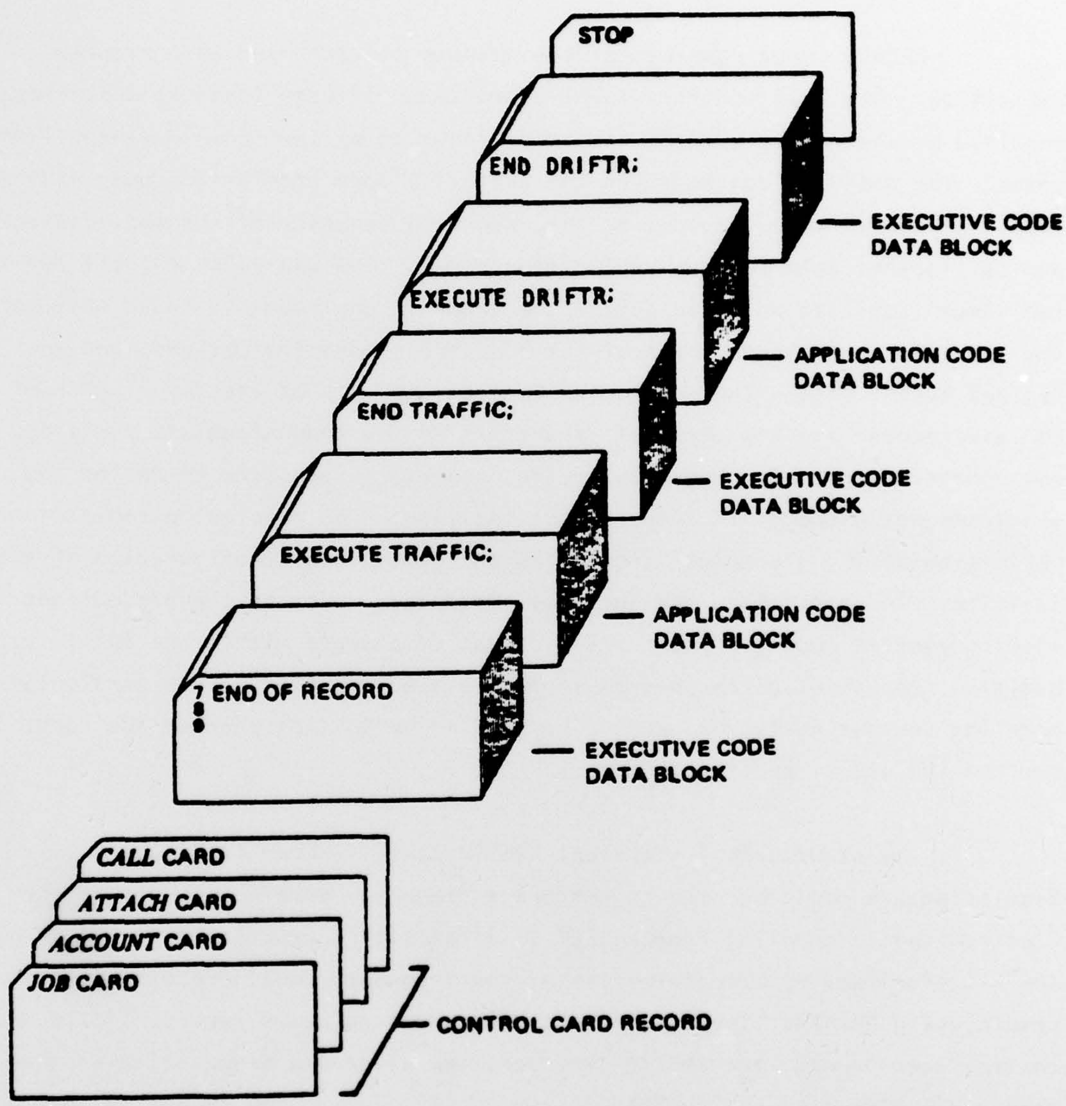


Figure 5.0-1. Typical PRESTO data deck structure.

6.0 PRESTO OUTPUT

PRESTO generates three types of output. The first type of output consists of two-dimensional plots and tabulated listings of time domain waveforms and frequency domain spectra. The second type consists of statistical prediction of the functional response of a facility. The third type consists of parameters placed in the data base by the application codes. These parameters can be tested to control the sequencing of the application codes or printed out in a user-generated report format.

7.0 CONCLUSIONS

The PRESTO code has been developed for the analysis of electronic circuits in an EMP environment. It includes codes (modeling library) for modeling the electromagnetic response of equipment in an EMP environment, codes (application codes) for performing the computational analysis requested by the user and an executive code providing the interface between engineering user and the application codes.

A modular approach was used in developing PRESTO. The modular approach allows additional system analysis, other than EMP analysis (e.g., radiation, blast, thermal, shock, drist structures ...), to be incorporated in PRESTO with a relatively small effort.

8.0 RECOMMENDATIONS

The PRESTO code should be maintained for use by the scientific community. As advances in the state-of-the-art and new requirements for EMP systems analysis become known, they should be included in PRESTO.

The PRESTO code should be expanded to meet the requirements of other system analysis by 1) adding the appropriate application codes to PRESTO, and 2) modifying the data display and graphical presentation of data within PRESTO, as required.

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